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Methods of Harvesting and Irrigation in Relation to Moldy Walnuts

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METHODS OF HARVESTING AND IRRIGATION IN RELATION TO MOLDY WALNUTS*

By L. D. BATCHELOR†

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INTRODUCTION

SERIOUSNESS AND DISTRIBUTION OF THE MOLD

For many years the prevalence of mold on walnut kernels has been one of the important causes of reduction in grade of nuts and therefore of loss of money to the walnut growers. A dark discoloration of the kernels is frequently, but not invariably, associated with the mold. In certain sections this trouble has been very bad the past three or four years.

* Paper No. 109, University of California, Graduate School of Tropical Agriculture and Citrus Experiment Station, Riverside, California.

† The author wishes to express his sincere appreciation for the many helpful suggestions in regard to this investigation, made by Dr. J. T. Barrett, Professor R. S. Vaile and Mr. Carlyle Thorpe. The arduous task of cracking thousands of nuts to obtain data was accomplished by the coöperation of Mr. D. C. Wylie of the Field Department of the California Walnut Growers' Association.

The extreme coastal districts and the hot inland regions have not been seriously troubled with mold. In the intermediate sections both the mold and the black kernels have frequently given a great deal of trouble. The hot inland valley sections may be troubled with a high per cent of black kernels even in the absence of mold. The most serious trouble with moldy nuts is usually found on sandy soils.

The economic loss to the walnut grower can be realized by calling to mind the fact that a percentage of over 10 per cent of poor nuts in any lot will necessitate the sale of the whole lot as near-grades,[1] at a probable reduction of 30 to 35 per cent of the value of first-class nuts, the exact value depending upon the actual percentage of poor nuts.

A further reduction in the percentage of good nuts to less than 75 per cent good, will necessitate the whole lot being sold as culls at a loss of another 30 per cent or more of the value of good nuts. The three grades of Santa Barbara soft-shell seedlings, sold by the California Walnut Growers' Association during the season of 1921–1922, returned the following prices to the growers: The first grade ('Diamond Brand')[2] $24.50 per hundred pounds; the near-grades averaged close to $15.00 per hundred pounds, and the culls $7.00 per hundred pounds.

It should not be inferred that all the nuts in the inferior classes are poor quality nuts, but rather that the percentage of poor nuts in the near-grades and culls is too large compared with the good nuts to justify their being sold as a first-class product. It should be clear from this discussion that it takes only a relatively small percentage of inferior nuts to lower the grade and the value of a lot of nuts, the majority of which are of a good quality. If a given lot of nuts is near the border line between the above grades, only one or two pounds of moldy nuts per hundred, may change the commercial value of the whole lot $7.00 to $8.00 per hundred pounds. Most of the moldy nuts cannot be sorted out in the packing house; thus great losses have been experienced in the past which were unavoidable by any means of grading or sorting practiced up to the present time.

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[1] 'Near Grades' are an inferior commercial grade in which the good nuts comprise only 75 per cent to 89 per cent of the total. The rest are moldy, shriveled, sun-burned, and generally inedible.

[2] 'Diamond Brand' is the trade name for the best grade of nuts shipped by The California Walnut Growers' Association and is guaranteed to contain at least 90 per cent perfect nuts.

The efforts of the walnut growers during a period of practically a year are expended on producing high-grade nuts. Good nuts can be changed like magic into the cull class in a week or ten days of improper handling. The work herein reported has shown that the nuts which are finally graded as culls because of mold or dark kernels, were without question first-class nuts at their maturity, a period which should coincide with the beginning of the normal harvest season.

SPECIFIC FUNGI CAUSING MOLDY NUTS

The particular fungi which cause the mold in walnuts have been studied during the past three years by Dr. J. T. Barrett of Citrus Experiment Station, Riverside, to whom the writer is indebted for the following statements:

"Mold in walnuts is not, strictly speaking, a specific disease, therefore, not necessarily confined to the action of a single specific organism. Many fungi and bacteria may grow for a time, upon matured parts of plants which offer suitable conditions of moisture and nutrient material, without actually destroying much of the tissue. The checking of the favorable conditions checks the growth of the organism. Therefore, it was no surprise to find that several fungi could cause moldy walnuts. No doubt many others would produce a similar effect were they present in the groves in sufficient quantity, and at a time when the nuts were in the proper stage for infection.

"Determination of the fungi most commonly associated with the moldy nuts was by means of cultures made by transferring pieces of the mold or mold-bearing tissue of the kernel to a suitable nutrient medium, usually glucose potato-extract agar. Usually within a week to ten days sufficient growth had taken place to make the determination possible. The many cultures made represented sample collections of nuts from more than twenty-five groves distributed in twelve of the main walnut-growing sections.

"The result of these studies revealed that by far the most prevalent fungus in moldy nuts is Alternaria, a genus containing many species, some of which cause very serious diseases of plants, many others occurring as saprophytes only. A little more than seventy-six per cent of the total number of nuts cultured were infected with Alternaria. Less than one per cent showed some other fungus associated with the Alternaria. While no attempt has yet been made to determine the species, the character of growth and spores in the majority of the cultures examined indicates that one species principally occurs.

"The largest number of cultures were made from nuts collected from the six districts most seriously troubled with moldy nuts. It is interesting to note that eighty-five per cent of these cultures developed Alternaria.

"Several other fungi were found in moldy nuts, but not at all consistently, and in a number of cases ranging from one-half to five per cent of the total number of cultures.

"The genera represented are Penicillium (blue and green mold), Cladosporium, Fusarium, Macrosporium (very similar to Alternaria), Mucor, and Sclerotinia (form with small sclerotia). About five per cent of the cultures were negative, and two per cent developed fungi that were sterile and not determined.

"While these studies to date are of a rather preliminary character, the evidence is sufficient to indicate very strongly that the fungus genus most responsible for the moldy nuts, during the past three years is Alternaria. How many species are concerned has not been determined. This with a number of other phases of the problem is to be further studied."

APPEARANCE OF MOLD ON WALNUT KERNELS

In the worst cases of mold the abundance of fungous growth, known as mycelium, is seen as a light to grayish-colored cottony growth on the kernels and inner walls of the shell. If the growth is only slight and largely confined to the diaphragm of the shell, it may not be detected. On the other hand, by the aid of a magnifying glass, strands of fungous mycelium may be detected on the kernel of many first-grade nuts, indicating that under suitable condition most nuts would probably be subject to infection.

On the drying of the nuts the mold dries also, but does not by any means disappear. It retains its fluffy appearance but may collapse somewhat on removal of the shell. There is not a marked difference in appearance of most of the various mold fungi as seen on the kernel. Sclerotinia and Fusarium are usually distinguishable from Alternaria, Macrosporium, and Cladosporium, although one may be frequently mistaken.

ENTRANCE OF MOLD INTO NUTS

Among the many thousand nuts which have been cracked and examined in connection with these studies, no mold has been found in a nut which at the time of examination was incased in a sound husk free from visible cracks and in crisp condition free from

decay. The mold commonly starts to grow in the cracks of the husk which accompany maturity, and spreads thence to the lining of the husk; it quickly spreads through the base and suture of the nut and thence to the diaphragm, and the pellicle of the kernel.

Nuts frequently drop to the ground with the green husk intact. If such nuts lie on the ground a few days the husks begin to decay. Alternaria is the most common cause of this decay. A soft and decayed spot usually first appears on the apex of the shuck. In such cases the mold spreads to the kernel by passing through the suture at apex of the nut.

Even in the worst cases of mold the fungus is superficial on the pellicle and does not actually affect the eating qualities of the kernel except as it presents an inedible appearance.

OCCURRENCE OF MOLD IN SEEDLING AND BUDDED NUTS

The trouble with mold has been much worse among the seedling groves than in the 'budded'[3] ones. This difference is mainly due to the fact that the budded varieties are more apt to drop the nuts from the tree free from the husk.

Many of the old seedling trees are characterized by a high percentage of the nuts dropping as green 'stick-tights.'[4]

The seedlings which more nearly approach the paper-shell type are more likely to shed the nuts as green stickers than the typical Santa Barbara soft-shell type.

The budded varieties, especially of the Santa Barbara soft-shell type such as Placentia and Chase, are, however, not entirely free from this trouble. Moldy nuts have occurred among both of these varieties to a serious degree, when for one reason or another the conditions have been favorable to mold development. The fact that the nuts of budded varieties usually drop free from the shucks is not the only factor which lessens the likelihood of mold among this class of nuts. Another reason is the fact that the majority of the budded groves are younger than the seedling groves, and for that reason are not as apt to become drought-stricken during the growing season as the older trees. As will be shown later, there is a correlation between drought and mold.

[3] The term 'budded' walnut tree is a trade name to designate the most desirable commercial varieties of nuts which may be propagated by budding or grafting them on black walnut roots.

[4] The term 'stick-tight' has become universally used by walnut growers to designate the nuts which drop to the ground with the husks sticking to them.

VARIATION AMONG SEEDLING TREES

EXTENT OF VARIATION

A group of eighty seedling trees have been under observation for the past three years. The prevalence of moldy nuts produced by the respective trees has varied greatly each year. The range and mean per cent of moldy nuts per tree are shown in table 1. At least fifty[5] nuts per tree were examined in each sample.

TABLE 1

RANGE OF VARIATION AND MEAN PER CENT OF MOLD FOUND IN NUTS FROM A GROUP OF SEEDLING TREES

Year	Total per cent of mold in clean nuts	
	Range among individual trees	Mean of all trees
1920	0—56	16
1921	0—24	7
1922	0—48	11

It is very apparent from table 1 that a group of seedling trees is an extremely variable population as regards this character of susceptibility of the nuts to mold. One tree may produce nuts which are free from mold, while possibly the adjacent tree produces 20 to 50 per cent moldy. Some of the wide variation is probably due to the inherent tendency of certain trees to produce stick-tight nuts, which are more apt to mold than clean nuts.

Some of the apparent variation in the percentage of moldy nuts from different trees may be due to the impracticability of harvesting the crop from each seedling tree when the nuts are in exactly the same state of maturity. Again the variation in the soil and subsoil makes it impossible to have the available moisture in the root zone of each individual tree alike. Such a variation in moisture is bound to be reflected in maturity of the crop, especially in the ease with which the nuts are husked, with a consequent prevalence of mold. From a practical point of view, it is important to know that some particular trees are much more likely to produce moldy nuts than others, as it may become advisable to segregate the moldy nuts in the orchard.

[5] It was found by experience that a sample of fifty nuts gave practically as accurate results as one hundred or more, provided the respective lot from which the sample was drawn was properly mixed, so the laws of chance came into fair play.

LIKELIHOOD OF INDIVIDUAL TREES PRODUCING MOLDY NUTS YEAR AFTER YEAR

The probability that certain trees may produce a large per cent of moldy nuts year after year has been shown to only a small degree by the studies of the past three years. Even though there is a small correlation between the percentage of moldy nuts from individual trees, comparing one year with another, there are many exceptions to this general rule. A strict interpretation of the statistical data[6] at hand not only shows the uncertainty of foretelling the relative amount of mold from individual trees in the future from records of the past; but the harvesting and curing experiments herein set forth show that these last mentioned factors are largely responsible for the prevalence of favorable mold-producing conditions.

RELATION TO SIDE-BLIGHTED NUTS

Inasmuch as the mold organism usually enters the husk after it starts to crack, it was thought that the mold might enter the small fissures in the husk caused by the form of walnut blight commonly known as side-blight. Many nuts which are side-blighted to a slight extent mature as good nuts, even though the husk may be affected with blight. Such blight cankers may not fully penetrate the husk sufficiently to stain the shell of the nut, even though the husk is clearly ruptured by the blight.

During the middle of the 1922 growing season, a large number of side-blighted nuts were covered with gauze bags so the nuts could be identified at harvest time. Likewise an equal number of healthy nuts were covered. Upon examination at harvest time the blighted nuts showed a slightly higher per cent of moldy nuts than the healthy nuts. The difference was more marked among stick-tight nuts than those which dropped free from the husks. A larger per cent of the side-blighted nuts were finally stick-tights than in the case of the healthy nuts.

[6] A detailed presentation of the statistical data is not called for at this time. It is sufficient to state here the correlation coëfficients for the per cent of moldy nuts per individual tree in both clean-nut and stick-tight classes were calculated, comparing the following harvest seasons: 1920 with 1921; 1920 with 1922; 1921 with 1922. Although all six coëfficients were positive, the low average of only .33 with a probable error of .07 shows only a low degree of probability that a tree will produce markedly moldy nuts year after year, other factors being equal.

Although there is a positive association of side-blight and mold, it is doubtful if this is a very important factor. Where there is a large enough percentage of mold to be a serious commercial consideration, the majority of cases become infected by other means than through blight cankers in the husks.

RELATION OF CONDITION OF NUTS AT HARVEST TO PRESENCE OF MOLD

MATURITY OF NUTS

The relation of the mold to the progress of the ripening of the nuts was suggested from the records of 1920. This investigation also showed a possible relation of harvesting methods to moldy nuts. Twelve thousand nuts were cracked to obtain this test, relative to the relation of harvest methods to moldy nuts. The nuts were equally divided into three lots: First, nuts which were picked from the trees when matured so the husks were starting to crack; second, clean nuts from ground; and third, stick-tights, the husks of some of which were black and dry when they fell, while others were originally mushy but had lain around until the husks were dried up. The percentage of mold in these three classes is shown in table 2.

TABLE 2

PROGRESS OF MOLD DEVELOPMENT IN NUTS AT DIFFERENT STAGES OF MATURING, AND CONDITIONS AT THE SAME DATE OF HARVEST (1920 CROP)

Classification	Moldy culls	Moldy but passable	Total mold
Nuts picked from trees when husks started to crack	6%	4%	10%
Clean nuts from the ground	7%	8%	15%
Black stick-tight nuts from ground	13%	14%	27%

The moldy nuts were divided into two classes according to the amount of mold present: (*a*) moldy culls; (*b*) moldy but passable. In the latter class the mold was clearly visible on the kernels, but not bad enough to condemn them as culls. At the same time there was a certain additional percentage of nuts which showed only such small traces of mold that they were classed as first-class nuts.

It is clear from a study of the summary that a delay in harvesting is bound to permit the mold to increase. Even the nuts picked from the trees were 10 per cent moldy. As some of this mold was passable, however, it would not have barred them from the best grade if they had all been periodically harvested as soon as the husks cracked. Many of the nuts in the lots picked off the trees had been held in the clasp of the partly opened husks for several days. The prompt harvesting of the nuts would have prevented the development of the mold, and have made the whole crop grade as Diamond Brand. A delay of several weeks would have allowed the whole crop to become so moldy that it would have graded as near-grades or culls. This point is brought in again in several of the following summaries:

MOLD INCREASE AS HARVEST SEASON ADVANCES

(Harvested according to ordinary methods)

Harvest and cracking records were kept from a group of trees near Anaheim during 1922. The nuts were picked up three or four times between September 28 and November 1. The trees were shaken each time, except at the first picking. One hundred nuts per tree were cracked at each picking to determine the amount of mold in the clean and stick-tight nuts. Table 3 shows the increase in the percentage of mold as the harvest season advanced.

TABLE 3

INCREASE IN PERCENTAGE OF MOLDY NUTS AS THE HARVEST SEASON ADVANCED

	1st pick (Sept. 23-28)		2d pick (Oct. 10-14)		3d pick (Oct. 25-Nov. 1)	
	Moldy culls	Moldy but passable	Moldy culls	Moldy but passable	Moldy culls	Moldy but passable
Clean nuts	3%	6%	4%	9%	4%	10%
Dry stick-tights	9%	16%	12%	18%	15%	28%
Green stick-tights	1%	5%	23%	27%	.....	.....

Table 3 as well as table 2 shows that the dry stick-tight nuts are much more likely to be moldy than clean nuts.

This is again brought out in table 4 which shows a summary of the records of all three years. The main purpose of table 3, however, is to show the increase in percentage of moldy nuts as the season advances.

With the clean nuts and the black, dry stick-tights there was an increase in moldy nuts, comparing the first pick with the second one. Still further increase of mold was noted in the black stick-tights between the second and third picks.

This big increase in mold is bad enough in the clean nuts and black stick-tights, but an even greater increase is shown by the green stick-tights.

This last mentioned class of nuts was practically free from moldy culls at the first picking. Twelve to fourteen days later, when the trees were shaken for the first time, the green stick-tights were 50 per cent moldy with 23 out of every 100 nuts reduced to moldy culls. Some of the green stick-tights of this second pick were already on the ground before the trees were shaken. Possibly 50 per cent of them were shaken off.

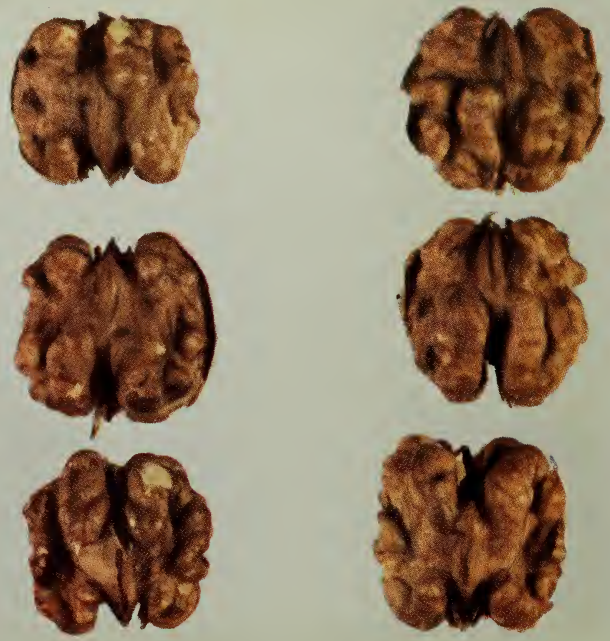
It is interesting to note what 100 pounds of the green stick-tights were worth at the first pick compared with the second one.

With such nuts originally grading as Diamond Brand when properly harvested, they were worth $22.50 per 100 pounds. Although there were 50 pounds of good nuts in every 100 pounds of the second pick, they could not be sorted out of the near-grades and culls. At the very best the whole lot could scarcely be counted on to grade as near-grades, valued at $15.00 or less per 100 pounds. A few more days delay in harvesting would, no doubt, have made culls of them, worth possibly $7.50. It is only a matter of combining plain arithmetic and good judgment to see that it would pay big dividends to speed up the harvest of green stick-tights, even to the extent of spending fifty cents per 100 pounds or more as an extra bonus for harvesting and shucking this type of nuts. It would also require, no doubt, more personal supervision of the laborers by the grove owner, which is a good thing on general principles, and would be well paid for in such a case as above illustrated.

MORE MOLD AMONG STICK-TIGHTS THAN CLEAN NUTS

In tables 2 and 3 it has already been shown that stick-tights are more apt to be moldy than are clean nuts. The following table summarizes the observations for all three years. With the large number of nuts observed (28,451) to make this comparison, the small errors of sampling, and the personal errors of judgment have been leveled by the laws of chance. It becomes a practical certainty that stick-tight nuts at harvest are likely to include somewhat more than twice as many moldy nuts than are the clean-shelled nuts.

a. Green "stick-tights," husks still firm.



b. Green "stick-tights," husks partly soft.

c. Green "stick-tights," husks become partly black and mushy.

d. Green "stick-tights," same as lot (a) but left on ground 11 days until husks became mushy.

Fig. 1.—Progress of kernel discoloration in "stick-tight" nuts due to delay in shucking.

(Courtesy of California Walnut Growers Association)

TABLE 4

PERCENTAGE OF MOLDY NUTS IN CLEAN AND STICK-TIGHT NUTS
(Result of 28,451 counts)

Class	Moldy culls	Moldy but passable	Total moldy nuts
Clean nuts	4%	7%	11%
Stick-tights	11%	17%	28%

The summary in table 4 includes four different crops from two groves. Nuts from 120 trees are about equally represented in this summary. In all cases when any considerable number of trees, say from 8 to 20, were grouped together, the trend of the results, without any exception, was the same as the above. Although it was clear at the end of the 1921 season that most of the moldy culls traced back to the stick-tight nuts, it was equally clear that a certain amount of mold occurred in the ordinary harvest of typical clean-shucked nuts.

The separation of these two classes of nuts in the orchards would no doubt lessen the trouble in grading the crop. It is stopping short of the real issue, however, to leave the question here without finding out more about the cause of even the small amount of mold in the clean nuts. The work was, therefore, enlarged in 1922 to include observations on the relation of the mold to harvesting methods as well as an attempt to reduce the number of stick-tights, and thus the large amount of mold.

RELATION OF DELAY IN HARVESTING TO PERCENTAGE OF MOLDY NUTS

The increase in per cent of moldy nuts, heretofore discussed in table 3, took place under ordinary harvesting conditions.[7] The trees were shaken at each picking, except the first one, and all the nuts picked up. Most of this increase in mold took place while the nuts were still on the trees, held within the clasp of the partly opened husks.

With this increase in mold under normal conditions of harvesting, it is now of interest to see what takes place when the nuts are

[7] The nuts are gathered two or three times by the ordinary harvesting methods. Frequently the nuts are allowed to lie on the ground in the grove from a week to ten days between pickings.

allowed to lie on the ground for several weeks, as they often do, under slack harvesting methods. Several trials were made at the beginning of the 1922 season. Nuts from the first picking, both clean and stick-tights, were left on the ground in the groves to determine the effect of this delay of harvesting on the mold. The first counts of the mold were made when the nuts would ordinarily be picked up (September 20 to 29). The second count from the respective groups was made a week or ten days afterward, and the third count (November 1), at the end of the harvest period.

The rapid increase in mold is shown by table 5, which summarizes the results of two tests.

TABLE 5

RAPID INCREASE IN PERCENTAGE OF MOLDY NUTS BY DELAY IN HARVESTING NUTS WHICH FELL AT BEGINNING OF SEASON (NUTS FROM FIRST PICK LEFT ON GROUND IN ORCHARD)

	1st crack (Sept. 28)		2d crack (Oct. 12)		3d crack (Oct. 21)	
	Moldy culls	Moldy but passable	Moldy culls	Moldy but passable	Moldy culls	Moldy but passable
Clean nuts	6%	12%	16%	10%	15%	11%
Black stick-tights	10%	17%	20%	18%	19%	18%

The rapid increase in the mold on these early ripening nuts occurred during the first week or ten days of harvest. After this time the nuts were largely cured on the ground, and there was no increase of mold from then until the end of the season. In fact these early nuts from the first pick were changed from Diamond Brand to near-grades by a delay of eight to ten days in picking them up. On the other hand, the third picking of stick-tights summarized in table 3 shows even more mold than the stick-tights just mentioned which laid on the ground for nearly forty days. This is due to the fact that most of this last class tabulated in table 5 were dry and crisp when they fell, while the third regular pick included many mushy stickers.

This brings us to the necessity of a somewhat clearer understanding of stick-tights. There are two or three distinct classes produced by as many distinct causes and with radically different kinds of kernels in them.

First, there are the dried-up black-husked stick-tights, the husk of which usually turns completely black while hanging on the tree. Such stick-tights are caused by a stem rot which may be in evidence as early as the middle of August. Many of the nuts in this class are borne in the centers of the trees, a fact which shows that their condition has no relation to heat or sunburn. Such nuts when picked off the trees usually show about 10 per cent moldy culls, and from 20 per cent to 40 per cent moldy but passable kernels. About 50 per cent usually show good, sound, white kernels. The kernels in this class, as a whole, are not quite up to normal plumpness. No doubt the premature stopping of the growth of the nut by the rot of the stem is responsible for the lack of plumpness.

The black, dry stick-tights discussed above, however, usually fail to account for many of the dark-meated culls, and the high percentage of mold that may be found under certain trees, or in certain loads of near-grades which reach the packing-house. With this fact in mind, a close account was kept of the second type, the green stick-tights, during the 1922 season. The green stick-tights are usually associated with lack of late summer irrigation. Many counts of the mold were made of samples of these green stick-tights which were allowed to lie on the ground in the grove until they became mushy. This mushy condition of the stick-tights exists all too often in many commercial groves. A large lot of green stick-tights were gathered on September 20, and will serve as an example of other similar experiments. A sample of 100 nuts was cracked on this date. The remainder of the lot were left in the grove with the husks on them and cracked as noted in table 6. A rapid increase in the percentage of mold followed as the husks became mushy. Finally, some time before the end of the season, the husks were completely dried up, and the nuts thus resembled the black stick-tights.

TABLE 6

SHOWING INCREASE IN PERCENTAGE OF MOLDY NUTS IN GREEN STICK-TIGHTS LEFT IN THE GROVE THROUGH THE HARVEST SEASON

When picked up Sept. 20		Left with husks on, on the ground					
		Sept. 28		Oct. 12		Nov. 1	
Moldy culls	Moldy but passable	Moldy culls	Moldy but passable	Moldy culls	Moldy but passable	Moldy culls	Moldy but passable
1%	2%	15%	16%	17%	17%	13%	43%

The green stick-tights which were husked as soon as the husks were wrinkled slightly and before they decayed, showed only 3 per cent total moldy nuts, while the kernels were notably white and of fine quality. After lying on the ground through the harvest season the total mold was 56 per cent instead of 3 per cent. Practically all the kernels were amber or black at the last sampling, and in fact, the whole lot were culls pure and simple. The outside of the shell, except for a little stain, showed no clue to the condition of the meats. Green stick-tights, handled somewhat as in this experiment, produce many of the near-grades and culls. They account for more trouble than the black, dry stick-tights on the trees, for the latter, as noted before, may have 50 per cent of good meats. In France the nuts are gathered green and husked, and are seldom moldy. This is in harmony with the above observations and probably accounts for the lack of mold in the French nuts. The colored cuts in figure 1 are presented to show the change in grade of the nuts due to the white kernels of a green stick-tight turning to amber or black, if the husk is allowed to stay on it until it becomes mushy. Cuts *a*, *b*, and *c* show the progress of discoloration in a lot of nuts picked up from one tree at the same time but divided into three classes: *a*, firm green stick-tights; *b*, green stick-tights starting to soften; *c*, mushy stick-tights. The amount of mold in these classes cannot be shown by the photographs; the total per cent of moldy nuts in the above classes at the time the nuts were picked up was as follows: 0, 24 and 88 per cent, respectively. The nuts shown in cut *d*, were firm green stick-tights taken from the same lot of nuts as lot *a* at the time of picking, but left on the ground until they became mushy. During a period of eleven days the nuts lay in the grove as they would under natural conditions of slack harvesting methods. The total mold in lot *d* increased from 0 to 73 per cent. Meanwhile the kernels had turned from first-class white meats, as shown in cut *a*, to practically all amber meats and culls, as shown in cut *d*.

RELATION OF SUNBURNED NUTS TO PREVALENCE OF MOLD

While the mold in stick-tights is under consideration, the results of observations on sunburned nuts may also be considered, inasmuch as most sunburned nuts are also stick-tights. In the popular mind, sunburning and mold are walnut troubles which go hand in hand. The fact that the extreme cases of mold are not necessarily tied up with sunburned nuts, was shown without question during the

present season. Most of the sunburned nuts drop with the green shucks on, showing a black spot on one side of them. Frequently the shucks are not cracked on such nuts, and seldom do they crack open enough to let the nut fall off the tree free from the shuck. The sunburned nuts often, in reality, are one form of the green stick-tights. Several large lots of these nuts were gathered and cracked periodically, to see if the mold was an unfailing partner to the sunburning on the nut. Table 7 summarizes an experiment which will illustrate the trend of all similar tests.

TABLE 7

SHOWING INCREASE OF MOLD IN SUNBURNED NUTS BY DELAYING HARVEST

Method of handling	Percentage of moldy nuts		
	Moldy culls	Moldy passable	Total moldy
Cracked as picked up (Sept. 29)	16	8	24
Shucked and cured in trays (cracked Oct. 12)	14	6	20
Left in grove with shucks on (cracked Oct. 12)	32	13	45
Left in grove with shucks on (cracked Nov. 1)	37	28	65

There is no question but that sunburned nuts, as they are gathered under normal harvesting conditions, are apt to be moldy, but it is equally clear that good marketable lots of near-grades can be made out of such nuts, if they are picked up promptly, shucked and cured normally. On the other hand, throwing such nuts up against the trees to be left there until they become mushy and shuck easier, will make culls out of practically the whole lot, with the mold increasing from 25 per cent up to 65 per cent or more.

In connection with this table the question may be raised, why the cured nuts showed less mold than those cracked when they were picked up. It has been consistently noticed that the same degree of mold shows up less in a thoroughly cured nut than in a green one. A small percentage of any lot of nuts will pass as practically sound when thoroughly cured which would be at least "moldy but passable" if judged before curing.

A sunburned nut is usually characterized by having one-half of the kernel blackened by the sun injury. For this reason they should not be mixed with the good nuts, regardless of the presence of mold. Although they might possibly be graded as near-grades, they

will not be a very commendable lot. Possibly such nuts should be kept separate in the grove, and sent to the cracking plant as culls, rather than lower the grade of good nuts by being intermixed with them.

RELATION OF CURING TO PERCENTAGE OF MOLDY NUTS

Clean nuts harvested in the ordinary manner are not likely to show any change in the percentage of moldy nuts due to any methods of curing.

Table 8 shows the result of a test taken in 1920. Clean nuts, harvested by ordinary methods, from the second picking were used for this test. Possibly some of these nuts had been on the ground in the grove a week or more before they were harvested.

TABLE 8

EFFECT OF RAPID AND SLOW CURING ON PERCENTAGE OF MOLDY NUTS

	Moldy culls	Moldy but passable	Total moldy
Sampled in grove when picked up	7%	8%	15%
Cured rapidly	8%	8%	16%
Cured slowly	7%	9%	16%

The rapidly cured nuts were spread in a thin layer in a laboratory and exposed to a breeze from a powerful electric fan for five days. The slowly cured ones were kept for five days in paper bags placed in a room where the humidity was maintained at nearly 100 per cent for the entire period. Both lots were then exposed to common-storage temperature and humidity until they were cracked. It is clear from the above summary that there was no further development of mold after the nuts left the orchard. Of course, all such cleaned-shelled nuts are partly cured as they lie on the ground in the grove.

RELATION OF IRRIGATION TO PERCENTAGE OF MOLDY NUTS

It has long been felt that the bad outbreaks of mold were associated in some way, with irrigation or cultural practice. Observations were made on this point during 1922, which show that irrigation late in the growing season to promote the cracking of the husks, making the nuts drop clean with few or no green stick-tights, is the first and most practical precaution to take in preventing moldy nuts. There is no doubt that in this indirect way, that is, through

the effect of irrigation on the green stick-tights, much of the trouble with moldy nuts is traceable first, to poor irrigation practice, and second, to lack of good harvesting methods.

Table 9 shows the results of an irrigation trial in the Anaheim district, during the 1922 season. Both plot A and plot C were well irrigated up to the first of August. After this date plot A received 7 acre inches per acre on August 8, and a like amount on September 7, while plot C received nothing. The rainfall was of no consequence from August 1 until the end of the harvest season. The contrast in the soil moisture condition in these two plots may be illustrated by the samples taken August 15 and September 12 summarized in table 9.

The samples were taken as soon as the soil could be cultivated following a heavy irrigation.

The amounts of moisture observed at these two periods are a close approach to the maximum water-holding capacity of the soil in plot A under field conditions.

TABLE 9

COMPARISON BETWEEN THE SOIL MOISTURE PRESENTS[8] IN PLOTS A AND C DURING THE LATTER PART OF THE GROWING SEASON AND THE FOREPART OF THE HARVEST PERIOD

Plot	Ft.	Hygroscopic point		Ratio of moisture content to hygroscopic point			
				Aug. 15 1922		Sept. 12 1922	
		A	C	A	C	A	C
	1	4.40	4.69	2.95	1.64	3.18	1.22
	2	2.64	3.47	4.03	2.02	4.13	1.35
	3	1.86	6.85	4.74	1.90	4.24	1.31
	4	4.71	8.02	2.10	1.67	2.48	1.10
	5	6.19	5.32	2.94	1.79	2.56	1.50
	6	3.71	4.72	3.37	2.08	3.13	1.57
	7	1.87	3.71	4.51	2.83	4.23	1.35
Mean				3.52	1.99	3.42	1.34

[8] The hygroscopic coëfficient was determined by the conventional indirect method originated by Briggs and Shantz. A 30-gram sample was used in all cases for this determination.

The moisture observed is stated as a ratio to the hygroscopic coëfficient. This seems to be the most effective way of acquainting the reader with relative moistures of the soil. For the information of those not used to thinking in the terms of present-day soil moisture studies, it may be stated that 1.47 times the hygroscopic coëfficient equals the wilting point of annual plants, while 2.71 times the hygroscopic coëfficient equals the moisture equivalent.

From data obtained previous to those presented in table 9, it is certain that the soil moisture in both plots A and C averaged above the wilting point throughout the first part of the growing season, April to July inclusive. From the first of August on, the soil moisture in plot A was kept well above the wilting point. Some time about the first of September, the soil of plot C had reached a dryness which would have caused annual plants to wilt and was approaching the hygroscopic point by the middle of September.

The contrast in soil moisture was clearly reflected in the maturity of the trees. The trees in plot A remained green throughout the harvest period of September and October. Probably less than 10 per cent of the leaves had dropped by October 30.

In contrast to this, the leaves began to drop from the trees on plot C during the middle of September, and by October 30 many of the trees were entirely bare of foliage. Probably 90 per cent of the leaves of the plot were on the ground at this last mentioned date.

TABLE 10

CONNECTION BETWEEN LACK OF WATER IN THE LATE SUMMER AND STICK-TIGHT AND MOLDY NUTS

	Per cent crop dropped as stick-tights[9]	Per cent of total crop moldy		
		Moldy culls	Moldy but passable	Total
Plot A (continually well irrigated)	22%	5%	12%	17%
Plot C (dry in latter part of August and in September)	52%	8%	17%	25%

The close relationship between the lack of soil moisture to stick-tights, and thus the prevalence of moldy nuts, is clearly shown by table 10.

In addition to the culls, due to mold, the dry plot produced about 20 per cent culls because of black meats from the mushy stick-tights. Meanwhile the well-irrigated plot showed less than 10 per cent additional culls from all other causes, and could easily have been graded as Diamond Brand. The entire crop from the dry plot, with 25 per cent culls, would hardly make the near-grade class.

[9] The dried-up black-husked stick-tights, discussed on pages 686 and 689 are figured in the total per cent of stick-tights for both plots. During a year when this particular type of stick-tight was less prevalent, the contrast in the percentage of stick-tights due to irrigation would be even more marked than during the 1922 season.

Each 100 pounds of nuts from the crop of the dry plot was actually worth at least $7.50 less than an equal amount from the well-irrigated plot. With only an average crop of nuts (825 pounds per acre) this would mean a loss of $61.88 per acre. An extra run of water would have been a paying investment.

If a grower has failed in following up his irrigation correctly, he can still rescue the crop in first-grade condition by proper harvesting. If he is slack in both of these practices, there is a very small likelihood of obtaining anything but near-grades and cull nuts.

SUMMARY

The work has shown conclusively that nuts will mold readily on the trees at any time after the husks start to crack, the mold starting its growth on the damp lining of the husk and finally spreading to the kernel. The vast majority of the nuts which are going to be moldy are in this condition before they reach the curing yards. The mold makes nearly all its growth while the kernels are still very moist. The first drying out at the beginning of the curing process checks any further development. The percentage of moldy nuts increases rapidly if the harvesting operations are delayed, especially if the nuts are still in the husks, even though they are partly cracked open and still on the trees. The percentage of moldy nuts is greater in stick-tights than in clean nuts. As the harvest season advances, the increase of mold is more pronounced in stick-tights than in clean nuts. The increase in percentage of mold among nuts left in the orchard is much greater in the case of green and mushy stick-tights, than in the case of black, dry stick-tights, since the latter dry up and partly cure while still on the trees. The percentage of the crop which falls as green or mushy stick-tights is much greater in groves which were not adequately irrigated during the very last portion of the growing season.

PRACTICAL RECOMMENDATIONS

1. Use enough late summer irrigation water so the trees hold their leaves through the harvest season, and the nuts drop free from the husks.

2. Hasten the harvest in general; shake the trees at the first picking, and have crew enough to go over the entire orchard once a week, shaking the trees each time.

3. Any trees that show a tendency to produce green stick-tights should be stripped of the crop the first time over and husked by hand, if necessary. Such nuts will have to be husked sometime; if they are taken in time they will be first-grade nuts, but if they are neglected, and the husks become mushy, they will be culls.

4. Knock off all the black stick-tights at the first picking, and husk them promptly.

5. Keep all the dry stick-tights, mushy stick-tights and sunburned nuts separate from the rest of the crop in the grove and curing yards, and deliver them to the packing-house separately. They are only near-grades at the best, and if they are kept separate from the rest of the crop, it will save much money and trouble in the packing-house not to have to attempt to pick them out of the better nuts. Furthermore, if the grower mixes too many of the black and mushy stickers in with the clean-shelled nuts, the whole lot may have to go as near-grades. Any attempt to fool the packing-house manager, by mixing good nuts with poor ones or *vice versa,* is very short sighted, not only for the immediate financial returns of the grower but for the good name of California walnuts. It is the first duty of the packing-house manager to grade the poor nuts out of the good ones, so don't add to his duties and the growers' expense by knowingly letting nuts with a high percentage of mold get in with the good lots.

6. The mold in walnuts is there, in the great majority of cases, before they reach the curing trays. Under any reasonably good method of handling the nuts on the trays, the mold will not increase during the curing process.

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